

**UNCLASSIFIED**

**AD 433618**

**DEFENSE DOCUMENTATION CENTER**

**FOR**

**SCIENTIFIC AND TECHNICAL INFORMATION**

**CAMERON STATION ALEXANDRIA VIRGINIA**



**UNCLASSIFIED**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

433618

CATALOGED BY JUC  
AS AD No.

433618

64-  
**BRL**

MEMORANDUM REPORT NO. 1530  
JANUARY 1964

THE PLASTIC RESPONSE TO INTERNAL BLAST LOADING OF MODELS  
OF OUTER CONTAINMENT STRUCTURES FOR NUCLEAR REACTORS

John W. Hanna  
William O. Ewing, Jr.

RDT & E Project No. 1MD10501A066  
**BALLISTIC RESEARCH LABORATORIES**

**ABERDEEN PROVING GROUND, MARYLAND**

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1530

JANUARY 1964

THE PLASTIC RESPONSE TO INTERNAL BLAST LOADING OF MODELS  
OF OUTER CONTAINMENT STRUCTURES FOR NUCLEAR REACTORS

John W. Hanna  
William O. Ewing, Jr.

Terminal Ballistics Laboratory

RDT & E Project No. 1MD10501A006

ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1530

JWRanna/WOEwing, Jr./rhg  
Aberdeen Proving Ground, Md.  
January 1964

THE PLASTIC RESPONSE TO INTERNAL BLAST LOADING OF MODELS  
OF OUTER CONTAINMENT STRUCTURES FOR NUCLEAR REACTORS

ABSTRACT

Presented are results of an experimental investigation of the plastic response of two geometrically scaled models of nuclear reactor outer containment vessels to internal blast loading. Tests were performed to study the ability of the containment shells to maintain integrity when subjected to large amounts of explosively released energy when unsupported (suspended in air), when half-buried in the ground, and when half-imbedded in concrete. The results show that the vessels tested will withstand a relatively large amount of explosively released energy, as compared to the "maximum credible incident" expected, provided that the welds are adequate and that access or other openings are properly reinforced.

## TABLE OF CONTENTS

	Page
ABSTRACT . . . . .	3
INTRODUCTION . . . . .	7
DESCRIPTION OF MODEL SHELLS. . . . .	8
EXPERIMENTAL PROCEDURE . . . . .	8
INSTRUMENTATION AND DATA REDUCTION . . . . .	13
TEST RESULTS . . . . .	13
DISCUSSION AND CONCLUSIONS . . . . .	15
ACKNOWLEDGEMENTS . . . . .	26
REFERENCES . . . . .	23
APPENDICES . . . . .	25
DISTRIBUTION LIST. . . . .	37

## INTRODUCTION

These Laboratories have been conducting for the Atomic Energy Commission studies in safety of outer containment structures for nuclear reactors. The studies have been both analytical<sup>1\*</sup> and experimental with particular emphasis being placed on the response of steel shells of various geometries to internal blast loading. An earlier report<sup>2</sup> gives results of scale model tests of the containment structures with explosives or propellants being used to simulate the scaled down energy releases from nuclear accidents. Results were presented for the elastic response phase of the test, including the effects of partial earth support and a comparison of response to transient internal pressures with strains developed under static internal pressure. One of the objectives of those studies was the verification of the scaling<sup>\*\*</sup> of the response of the shells to internal blast loading.

In those studies the structural response scaling law was verified for the elastic range. Further, determinations were made of the magnitudes of the dynamic strains generated on the shell surface for a given energy release within the shell.

Because a containment shell need only remain intact to perform its function, it can be allowed to deform plastically under transient pressure loading. Thus, studies of the response in the plastic range are desirable. The present work is a continuation of the early studies into the plastic range and concludes the experimental phase of the investigations.

To verify further the structural response scaling laws, Baker et al.<sup>3</sup> had performed a series of experiments on the response of scaled cantilever beams to blast loading from explosive charges detonated in air. The results of those experiments also verified scaling of the response for both the elastic and plastic ranges for these simple structures when subjected to blast loading.

---

\* Superscript numbers denote references listed at end of report.

\*\* The geometrical scaling law (similarity principle) states that the time histories of displacement and strain of a full-scale model resulting from rapid release of energy from an energy source can be predicted from measurements of these parameters in a scale model of the structure, provided that the scaling factor is applied properly. A thorough discussion of the model laws is given in Reference 3.

However, it is desired (if possible) to test plastic response scaling of the larger (and more complex) containment shell geometries, as well as to determine the ultimate strength of the models under blast loading.

#### DESCRIPTION OF MODEL SHELLS

The containment shell models used in both the elastic and plastic response tests were all cylinders with hemispherical end caps, of welded construction, fabricated from sheet steel. Figure 1 shows the shell geometry and principal dimensions of each shell in the series. Each of the four shells is a geometrical model of the next smaller shell scaled up by a factor of two. Figure 2 is a photograph of the shells as used in one series of tests.

The shells were all shop fabricated except the largest one (20-ft. dia.), which was field erected. Specifications stipulated that all units were to be made from the same type of steel (i.e., steels having the same elastic and plastic properties). The steel used in their fabrication conforms to ASTM specifications for Type A-283 Grade C. The shells were stress relieved in accordance with procedures outlined in Section VIII of ASME code for unfired pressure vessels.\*

#### EXPERIMENTAL PROCEDURE

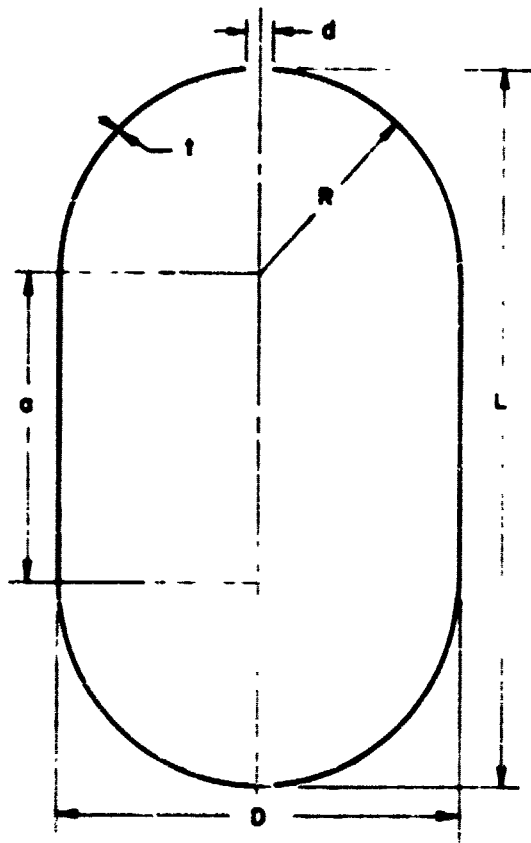
For the plastic response studies only dynamic tests were conducted. As in the earlier (elastic response) studies of these models, some of the smaller shells were instrumented with externally mounted resistance wire strain gages, SR-4, Type A-13, mounted at twelve locations. Along the cylindrical center sections, gages were positioned to measure both longitudinal and circumferential strains. Figure 3 shows schematically the strain gage locations.

The shells were subjected to internal transient loading from properly scaled,\*\* centrally located explosive charges (see Table I and Appendix A for charge weights used) and strain-time histories were measured at the various gage positions. The charges were lowered through the small opening at the top of the shell, suspended at the midpoint or below, and then detonated. The

---

\* Low temperature stress relief process, as developed by Linde, was used where required in the field erected vessel.

\*\* The scale factor is two, thus the charge weights increase by a factor of  $2^3$  for tests of successive sizes of shells.



SHELL NO.	D, FEET	R, FEET	L, FEET	FLET	t, INCHES	d, INCHES
1	2 1/2	1 1/4	4 3/8	1 7/8	1/16	2 1/2
2	5	2 1/2	8 3/4	3 3/4	1/8	5
3	10	5	17 1/2	7 1/2	1/4	10
4	20	10	35	15	1/2	20

**FIGURE 1-GEOMETRY AND PRINCIPAL DIMENSIONS OF SERIES OF SCALED CONTAINMENT SHELLS.**

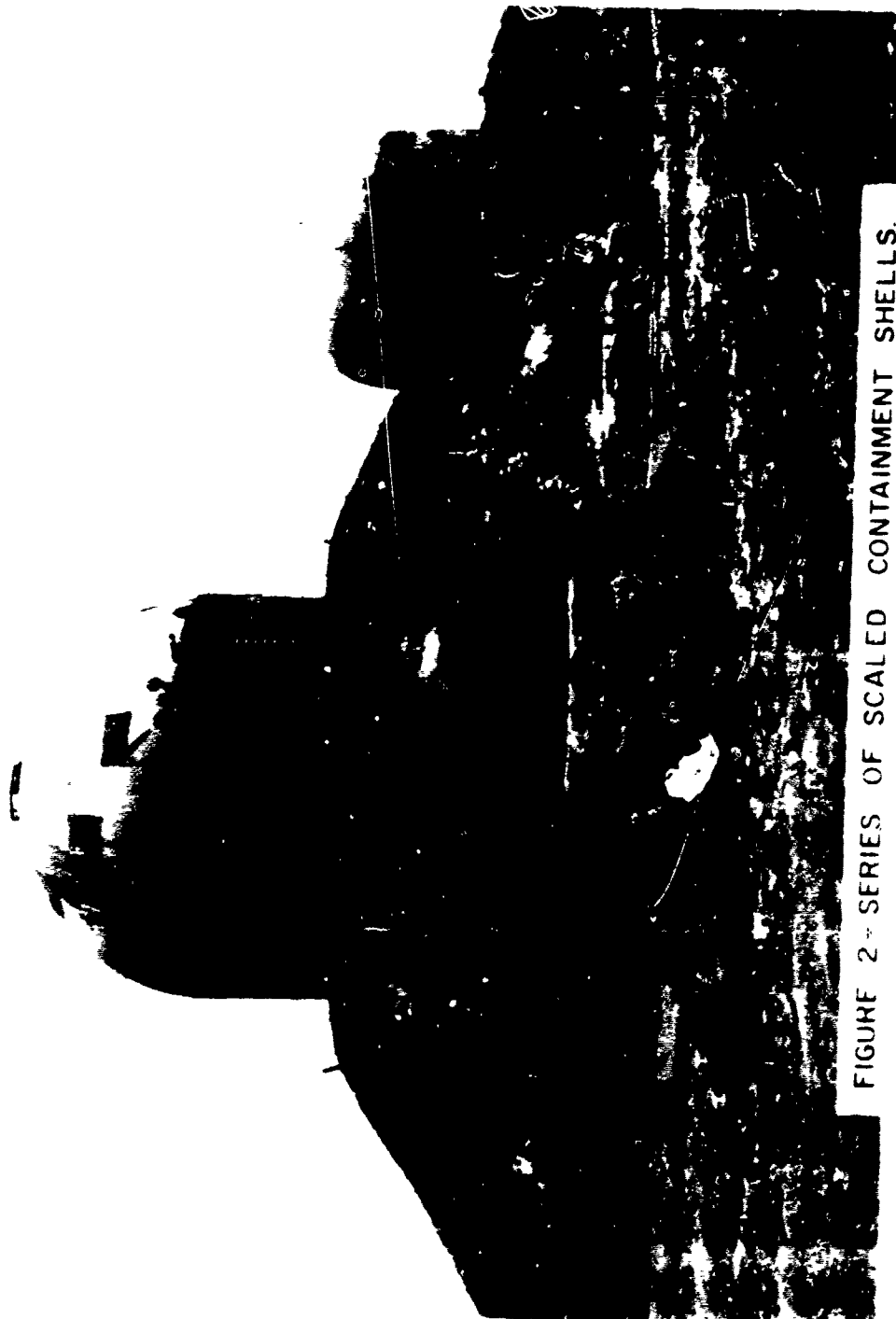


FIGURE 2 - SERIES OF SCALED CONTAINMENT SHELLS.

TABLE 1

## SUMMARY OF TESTS

Shell No.	Test Condition	Range of Explosive Charge Weights Used (lb.)	Charge Location	Total No. of Charges Detonated	Maximum Charge Before Failure (lb.)	Maximum Simulated Energy Released in Full Scale (cu'-Dia. Shell) before Failure (Wt.-Sec.)	Remarks
1	Shell suspended in air	1 1/8 - 1 3/4	Center	9	.00	-	Failed prematurely at weld.
		1 1/8 - 1	20" below center	7	-	-	Failed prematurely at weld.
2	Shell half-buried in earth	1 1/8 - 1 1/2	Center	8	-	-	Failed prematurely at weld.
		3/4 - 1 1/8	Center	9	13.94	27,885	All original welds replaced. Access hole reinforced. Welded inside and outside. Noticeable bulging at center. Failed by tearing around reinforcement ring in access hole. Numerous vertical cracks around shell.
3	Shell half-embedded in concrete	1 1/8 - 2	Center	13	1.46	13,774	Failed prematurely at weld.
4	Shell half-buried in earth	3 - 2 1/2 - 3 1/4	Center	7	14.94	17,593	Failed by tearing initiated at access hole. (Little plastic deformation apparent.)

\* See tables in Appendices for detailed round-by-round results.

\*\* Premature weld failures.

\*\*\* 1 lb. available - (1) Wt.-Sec.

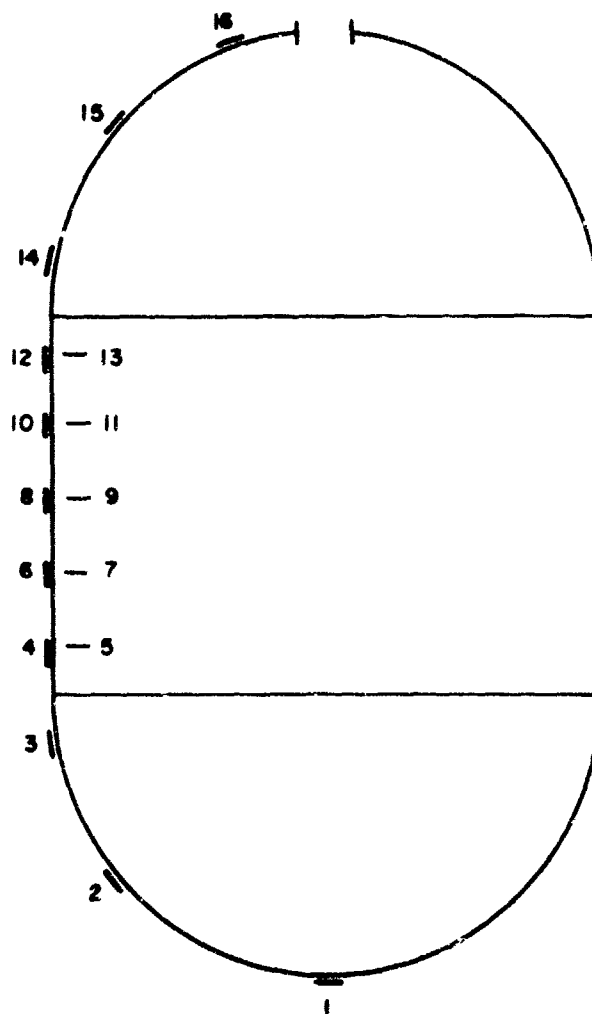


FIG.3-LOCATION OF STRAIN GAGES ON SHELL

strain-time histories were recorded with a high-frequency response, sixteen-channel, commercial recording system. Small spherical charges of 50/50 Pentolite\* were used, the charge weights being increased on successive tests.

Tests were performed with the models suspended freely in air by means of a rope sling (Shell No. 2), with the models partially supported by earth (Shell Nos. 2 and 3), and with the model (Shell No. 2) partially embedded in concrete. The charge sizes used were gradually increased until failure occurred.

#### INSTRUMENTATION AND DATA REDUCTION

The sixteen channels of strain gage information were amplified by d.c. amplifiers,\*\* displayed on eight dual-beam cathode-ray tubes, and recorded on moving photographic paper. Timing marks and calibration steps are automatically impressed on the photographic record. Peak strain amplitudes (wherever they occurred on the pressure-time trace) were read. Combined calibration and reading errors in measurement of strain amplitudes are estimated to be  $\pm 5\%$ .

#### TEST RESULTS

The test results are summarized in Table I, while the round-by-round data are presented in the Appendices. Table I indicates the range of charge weights used and location of charges in the models. Indicated also are the maximum charge weights which the models withstood without failing. The predicted maximum simulated energy release (expressed in megawatt-seconds) in a "full-scale" model (80-ft. dia.) shell is also given.

Of the four original models, only Shells No. 2 and 3 were tested in the plastic range. Three specimens of Shell No. 2 ruptured prematurely, the failure occurring at welded joints (see Figure 4). These models were instrumented with strain gages which are capable of indicating strains up to approximately 3%. The gages were used primarily to indicate the point at which plastic deformation began. Acceptable strain-time histories were obtained for most trials and

---

\* An explosive having a heat of detonation of 1220 cal./gm. (Reference DA TM-1910).

\*\* Having a frequency response flat from 0 to 100 KC.



FIGURE 4 - FAILURE OF CAP WELD - SHELL NO. 2

(before failure of gage leads) for some trials where shell failure occurred. It is to be noted that because of the premature shell failures all strains recorded are in the elastic range. Although detailed elastic response data for these models have been reported earlier,<sup>2</sup> the present data are retained and relegated to the Appendix. After replacing all original welds and reinforcing the access hole with a circular ring in one of the specimens, Shell No. 2 withstood successfully the blast from a series of explosive charge weights up to and including 3 lbs. Plastic deformation of this model was apparent after trial 5. An indication of the extent of deformation can be seen in Figure 5. Two small vertical cracks were observed in the weld at the juncture of upper cap and cylindrical section after detonation of a 3.45-lb. charge. The shell failed when tested with a 3.84-lb. charge (see Figure 6).

In the test of this model while half-embedded in concrete the shell withstood the blast from charge sizes up to and including 1-1/2 lb., but failed prematurely at the juncture of the lower cap and the cylindrical section from a 2-lb. charge.

The larger shell (Shell No. 3), tested when half-buried in earth, withstood the blast loading from charge sizes up to and including 15 lbs. without deforming plastically. The shell ruptured when tested with a 25-3/4 lb. charge. However, failure here was initiated as a tearing at the access hole and is not indicative of the true vessel strength. The only visible indication of plastic deformation was that at the midpoint (ground juncture). Figures 7 through 9 are photographs taken of this model after test. On request from the Atomic Energy Commission (because of possible further use in non-destructive testing), the largest (20-ft. dia.) model was not tested in the plastic range. No plastic tests were performed with the smallest model (Shell No. 1) as all specimens were destroyed in earlier tests.

#### DISCUSSION AND CONCLUSIONS

Although many of the early trials with the smaller models were hampered by premature weld failures, successful trials were achieved with one specimen after it had been rewelded. The failures appeared to stem in part from incomplete fusion and possibly from inadequate annealing after welding. The relatively thin material of the smaller models had been butt-welded on the outer surface. Further, one cap could be welded on the outside only, since installation of this



FIGURE 5 - PLASTIC DEFORMATION OF SHELL NO. 2



FIGURE 6 - FAILURE OF SHELL NO. 2

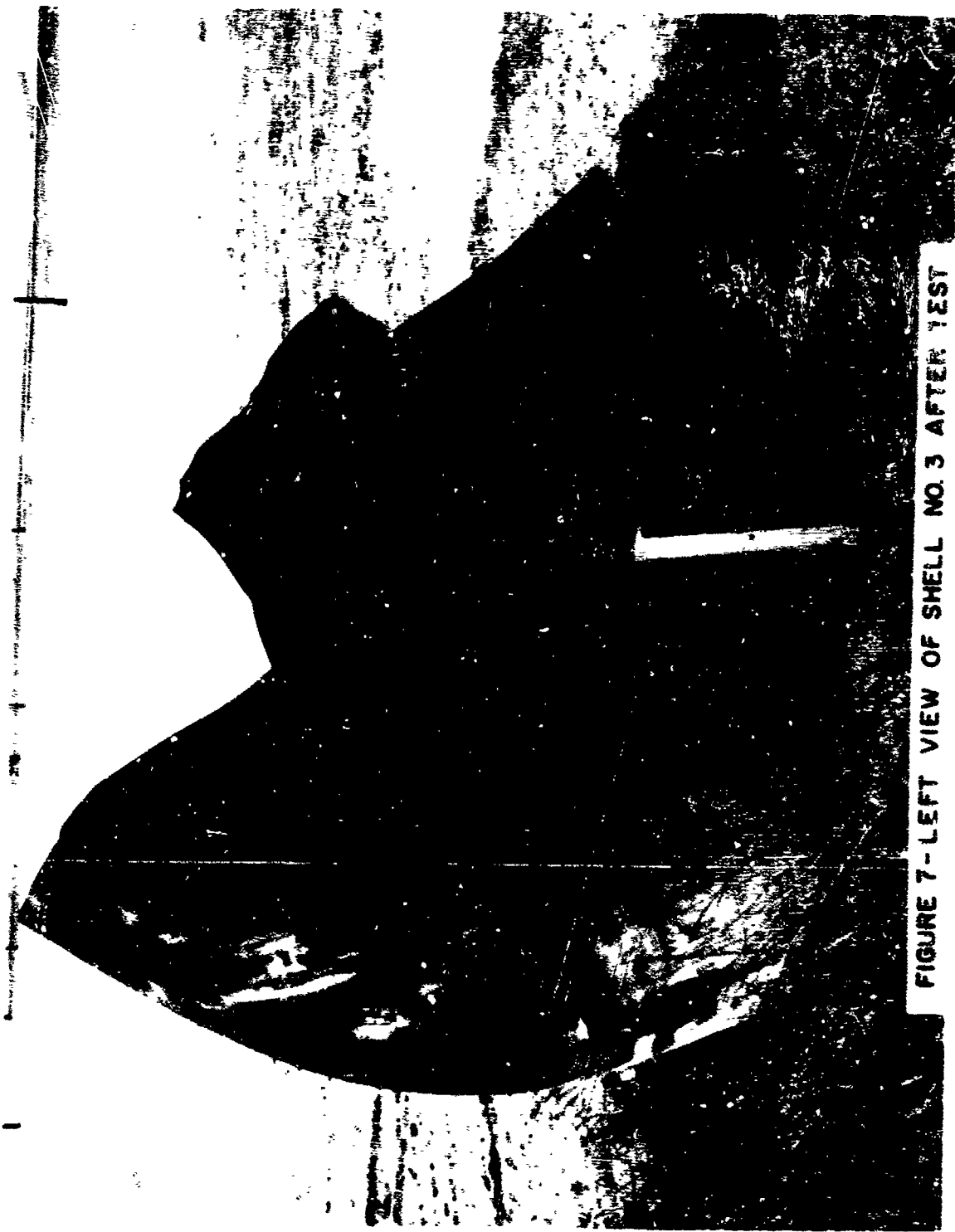


FIGURE 7 - LEFT VIEW OF SHELL NO. 3 AFTER TEST



FIGURE 8 - RIGHT VIEW OF SHELL NO. 3 AFTER TEST



FIGURE 9 - PLASTIC DEFORMATION OF SHELL NO. 3

cap closed the shell. This difficulty was not experienced with the larger vessel because of better accessibility for welding of the interior surfaces.

Although absolute results were obtained with only the smaller model (both access hole reinforced and adequately welded), one can estimate the charge sizes which would be required to cause failure of the larger vessels. The 5-lb. charge which Shell No. 2 withstood is equivalent to 24 lbs. in Shell No. 3 and 192 lbs. in Shell No. 4.

As can be seen from the data in Table I, the vessels of the configuration tested can withstand a large amount of explosively released energy while maintaining integrity.

It is of interest to note that the model sizes were chosen such that the largest shell of the series (not tested in plastic range) is a 1/4-scale model of that of the Air Force Nuclear Engineering Test Reactor.<sup>4\*</sup> As can be seen in Table I, the shells tested withstood many times the "maximum credible incident" of 1000 Mw-Sec postulated for this reactor. The adequacy of the shells is more convincing when it is remembered that test results from explosives tend to be "conservative", that is, a structure which will withstand a given amount of explosively released energy will withstand many times the same amount of energy released at a slower rate.<sup>\*\*</sup> One must be assured, of course, that all welds are at least as strong as the vessel itself and that access or other openings are properly reinforced. The cumulative effect of progressive testing on the ultimate shell response cannot be assessed, but it is believed that some degradation is inevitable.

An insufficient number of tests was conducted with eccentrically located charges to enable one to compare results with centrally placed charges. To test rigorously the structural response scaling law for the plastic case, many more successful trials would have been required. However, as stated earlier,

---

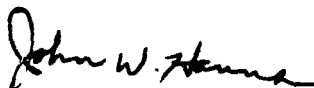
\* A blast effects study of a 1/4-scale model of this reactor was conducted by these Laboratories.

\*\* It is recognized that there are exceptions to this concept. An example would be the case where the pressure generated is allowed to build up in an enclosure and then released (possibly propelling a mass), in which case a relatively higher impulse would be obtained.

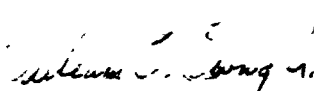
the structural response scaling laws have been verified with these models for the elastic range, and with cantilever beams for both the elastic and plastic ranges. Thus it is believed that one can extrapolate with confidence the results obtained here to "full-scale" models.

#### ACKNOWLEDGEMENTS

The authors are indebted to Mr. Orlando T. Johnson for technical supervision. Acknowledgement is also made of the assistance rendered by Messrs. M. Leigh, W. Smothers and C. Brown, who constituted the field crew.



JOHN W. HANNA



WILLIAM O. EWING, JR.

#### REFERENCES

1. Baker, W. E. The Elastic-Plastic Response of Thin Spherical Shells to Internal Blast Loading. ERL Memorandum Report No. 1194, February 1959.
2. Hanna, J. W., Ewing, W. O., Jr., Baker, W. E. The Elastic Response to Internal Blast Loading of Models of Outer Containment Structures for Nuclear Reactors. ERL Report No. 1067, February 1959.
3. Baker, W. E., Ewing, W. O., Jr., Hanna, J. W. Laws for Large Elastic Response and Permanent Deformation of Model Structures Subjected to Blast Loading. ERL Report No. 1060, December 1958.
4. Baker, W. E., Patterson, J. D., II Blast Effects Tests of a One-Quarter Scale Model of the Air Force Nuclear Engineering Test Reactor. ERL Report No. 1011, March 1957.

APPENDIX A

Round-by-Round Test Results

Plastic Response of Shells  
Round-by-Round Test Results

Shell	Trial No.	Test Condition	Explosive Charge Weight (lb.)	Explosive Charge Location	Remarks
2	1	Suspended in air	1/8	Center	
	2	"	1/8	"	
	3	"	3/16	"	
	4	"	3/16	"	
	5	"	1/4	"	
	6	"	3/8	"	
	7	"	1/2	"	3" tear at access hole
	8	"	3/4	"	Both cap welds failed
2	1	"	1/8	20" below Center	
	2	"	3/16	"	
	3	"	1/4	Center	
	4	"	1/4	20" below Center	
	5	"	3/8	"	
	6	"	1/2	"	
	7	"	3/4	"	
	8	"	1	"	Failed at weld
2	1	"	1/8	Center	Rewelded Shell
	2	"	"	"	
	3	"	"	"	
	4	"	1/2	"	
	5	"	3/4	"	
	6	"	1	"	18" long seam opened in top cap
	7	"	1	"	Weld repaired - Top cap separated at weld
	8	"	1-1/2	"	Weld repaired - Top cap failed at weld
2	1	Half-Buried in Earth	3/4	Center	Both caps blown off at welds
	2	"	3/4	"	Rewelded inside and outside and access hole reinforced.
	3	"	1	"	3" long crack in cap segment.
	4	"	1-1/2	"	Crack repaired.
	5	"	2	"	Slight bulging at midpoint of shell.
	6	"	3	"	Increased bulging at midpoint of shell.

Plastic Response of Shells  
Round-by-Round Test Results

Shell	Trial No.	Test Condition	Explosive Charge Weight (lb.)	Explosive Charge Location	Remarks
2	1	Suspended in air	1/8	Center	
	2	"	1/8	"	
	3	"	3/16	"	
	4	"	3/16	"	
	5	"	1/4	"	
	6	"	3/8	"	
	7	"	1/2	"	3" tear at access hole
	8	"	3/4	"	Both cap welds failed
2	1	"	1/8	20" below Center	
	2	"	3/16	"	
	3	"	1/4	Center	
	4	"	1/4	20" below Center	
	5	"	3/8	"	
	6	"	1/2	"	
	7	"	3/4	"	
	8	"	1	"	Failed at weld
2	1	"	1/8	Center	Rewelded Shell
	2	"	"	"	
	3	"	"	"	
	4	"	1/2	"	
	5	"	3/4	"	
	6	"	1	"	18" long seam opened in top cap
	7	"	1	"	Weld repaired - Top cap separated at weld
	8	"	1-1/2	"	Weld repaired - Top cap failed at weld
2	1	Half-Buried in Earth	3/4	Center	Both caps blown off at welds
	2	"	3/4	"	Rewelded inside and outside and access hole reinforced.
	3	"	1	"	3" long crack in cap segment.
	4	"	1-1/2	"	Crack repaired.
	5	"	2	"	Slight bulging at midpoint of shell.
	6	"	3	"	Increased bulging at midpoint of shell.

# Plastic Response of Shells (Cont'd.)

## Round-by-Round Test Results

Shell	Trial No.	Test Condition	Explosive Charge Weight (lb.)	Explosive Charge Location	Remarks
	7	"	3	"	Increased bulging at midpoint of shell.
	8	"	3.45	"	Two small vertical cracks in weld at juncture of upper cap and cylindrical section.
	9	"	3.84	"	Ten vertical cracks around shell at juncture of upper cap and cylindrical section. Reinforcement ring partially torn from access hole. Increased bulging of shell.
2	1	Half-Embedded in Concrete	1/8	Center	
	2	"	1/4	"	
	3	"	1/4	"	
	4	"	3/8	"	
	5	"	3/8	"	
	6	"	1/2	"	
	7	"	1/2	"	
	8	"	3/4	"	
	9	"	3/4	"	
	10	"	1	"	
	11	"	1	"	
	12	"	1-1/2	"	Three 1-1/2" long cracks at access hole.
	13	"	2	"	Shell failed at weld at juncture of lower cap with cyl. section. Upper portion of shell was blown about 200' into air. Concrete cracked on all sides.
3	1	Half-Buried in Earth	3	Center	
	2	"	4.94	"	
	3	"	8.44	"	
	4	"	9.88	"	
	5	"	11.63	"	
	6	"	14.94	"	
	7	"	25.75	"	Shell failed by tearing initiated at access hole.

**APPENDIX B**

**Strain Gage Data**

Round-by-Round Strain Gage Data  
5-Ft. Capped Cylinder Suspended in Air

Round No. 178  
Charge Weight - 3/16 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	-*
2	-
3	1400
4	1900
5	1500
6	900
7	2100
8	750
9	1300
10	820
11	1800
12	3300
13	1900
14	-
15	1100
16	900

Round No. 179  
Charge Weight - 1/4 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	1400
4	-
5	1500
6	1050
7	1800
8	1750
9	1700
10	1600
11	1500
12	-
13	1300
14	-
15	1050
16	1500

Round No. 180  
Charge Weight - 1/4 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	-
4	-
5	1000
6	700
7	1200
8	600
9	2200
10	800
11	1700
12	-
13	1200
14	-
15	1600
16	550

Round No. 181  
Charge Weight - 1/2 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	-
4	-
5	1400
6	1100
7	1500
8	920
9	2000
10	700
11	1800
12	-
13	2000
14	-
15	1600
16	2000

\*Dashes in these tables indicate that calibration step or trace was not impressed on the record.

Round-by-Round Strain Gage Data (Cont'd.)

Round No. 182  
Charge Weight - 3/4 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	-
4	-
5	1600
6	1200
7	2100
8	-
9	2300
10	1200
11	2300
12	-
13	2000
14	-
15	2500
16	1200

Round No. 187  
Charge Weight - 1/8 lb.  
Charge Location 20" below Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	710
4	500
5	810
6	-
7	900
8	400
9	-
10	550
11	900
12	570
13	1100
14	620
15	600
16	700

Round No. 188  
Charge Weight - 3/16 lb.  
Charge Location - 20" below Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	840
4	1400
5	1000
6	-
7	1200
8	800
9	1300
10	700
11	1100
12	900
13	1300
14	900
15	500
16	1100

Round No. 189  
Charge Weight - 1/4 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	1100
4	720
5	1400
6	-
7	1400
8	1000
9	2000
10	930
11	1500
12	1000
13	1400
14	1200
15	640
16	1000

Round-by-Round Strain Gage Data (Cont'd.)

Round No. 190  
Charge Weight - 1/4 lb.  
Charge Location-20" below Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	700
4	720
5	1300
6	-
7	980
8	810
9	1400
10	870
11	1300
12	1900
13	1100
14	880
15	810
16	690

Round No. 191  
Charge Weight - 5/8 lb.  
Charge Location-20" below Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	800
4	-
5	1100
6	-
7	1800
8	970
9	1200
10	700
11	1300
12	1800
13	1300
14	950
15	700
16	870

Round No. 194  
Charge Weight - 1 lb.  
Charge Location-20" below Center

Gage No.	Peak Strain $\times 10^6$
1	-
2	-
3	-
4	-
5	3400
6	-
7	3500
8	-
9	2200
10	-
11	2000
12	-
13	-
14	-
15	-
16	-

Round No. 220  
Charge Weight - 1/8 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	510
2	230
3	490
4	400
5	-
6	580
7	-
8	480
9	1300
10	490
11	-
12	350
13	1000
14	400
15	420
16	480

Round-by-Round Strain Gage Data (Cont'd.)

Round No. 221  
Charge Weight - 1/8 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	710
2	240
3	520
4	500
5	-
6	530
7	-
8	540
9	970
10	440
11	-
12	670
13	900
14	390
15	520
16	510

Round No. 222  
Charge Weight - 1/8 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	580
2	250
3	530
4	550
5	-
6	610
7	-
8	690
9	1600
10	530
11	-
12	570
13	1100
14	600
15	490
16	1100

Round No. 223  
Charge Weight - 1/2 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	1700
2	430
3	1200
4	1200
5	-
6	-
7	-
8	1200
9	1300
10	770
11	-
12	620
13	550
14	880
15	940
16	1300

Round No. 224  
Charge Weight - 3/4 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	1500
2	830
3	930
4	940
5	-
6	-
7	-
8	880
9	1300
10	-
11	-
12	550
13	1400
14	860
15	820
16	880

Round-by-Round Strain Gage Data (Cont'd.)

Round No. 225  
Charge Weight - 1.08 lb.  
Charge Location - Center

<u>Gage No.</u>	<u>Peak Strain x 10<sup>6</sup></u>
1	-
2	660
3	390
4	750
5	1500
6	750
7	-
8	940
9	1300
10	880
11	-
12	880
13	2100
14	-
15	1100
16	1200

Round No. 226  
Charge Weight - 1.08 lb.  
Charge Location - Center

<u>Gage No.</u>	<u>Peak Strain x 10<sup>6</sup></u>
1	-
2	730
3	1600
4	-
5	-
6	-
7	-
8	910
9	1400
10	830
11	-
12	830
13	1700
14	880
15	-
16	-

Round No. 227  
Charge Weight - 1-1/2 lb.  
Charge Location - Center

<u>Gage No.</u>	<u>Peak Strain x 10<sup>6</sup></u>
1	-
2	880
3	880
4	-
5	-
6	-
7	-
8	1300
9	930
10	-
11	930
12	1500
13	-
14	-
15	-
16	-

Round-by-Round Strain Gage Data  
5-Ft. Capped Cylinder Partially Imbedded in Concrete

Round No. 207  
Charge Weight - 0.12 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
9	630
10	430
11	1300
13	1400
14	480
15	1300

Round No. 208  
Charge Weight - 0.25 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
9	900
10	570
11	2300
13	1600
14	630
15	800

Round No. 209  
Charge Weight - 0.25 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
9	800
10	920
11	2400
13	-
14	620
15	540

Round No. 210  
Charge Weight - 0.37 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	-
9	540
10	1000
11	2700
14	880
15	750

Round No. 211  
Charge Weight - 0.37 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	1900
9	650
10	800
11	2900
14	1100
15	1300

Round No. 212  
Charge Weight - 0.52 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
1	3400
9	600
10	600
11	2200
14	760
15	1400

Round No. 214  
Charge Weight - 0.79 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
9	800
10	1200
11	2100
14	1700
15	1200

Round No. 216  
Charge Weight - 1.07 lb.  
Charge Location - Center

Gage No.	Peak Strain $\times 10^6$
9	830
10	1100
11	1800
14	1200
15	1700

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
20	Commander Defense Documentation Center ATTN: TIFCR Cameron Station Alexandria, Virginia 22314	1	Redstone Scientific Information Center U. S. Army Missile Command ATTN: C. T. Rogers Chief, Document Section Redstone Arsenal, Alabama 35809
1	Chief, Defense Atomic Support Agency ATTN: Document Library Branch Washington, D. C. 20301	1	Commanding Officer Watertown Arsenal ATTN: Technical Information Section Watertown, Massachusetts 02172
1	Commanding General Headquarters Field Command Defense Atomic Support Agency ATTN: FCTG-5 Sandia Base Albuquerque, New Mexico 87115	1	Commanding General U. S. Army Mobility Command Warren, Michigan 48090
1	Assistant Secretary of Defense (R&E) ATTN: Director/Atomic, B&C Warfare The Pentagon Washington 25, D. C.	1	Commanding General U. S. Army Chemical Corps Research & Development Command Washington 25, D. C.
1	Commanding General U. S. Army Materiel Command ATTN: AMCRD-RP-B Washington, D. C. 20315	2	Commanding Officer U. S. Army Chemical Warfare Laboratories ATTN: Librarian Technical Library, Bldg. 350 Edgewood Arsenal, Maryland 21040
1	Commanding General U. S. Army Materiel Command ATTN: AMCRD-DN Washington, D. C. 20315	1	Director Waterways Experiment Station U. S. Corps of Engineers ATTN: E. P. Fortson, Jr. Vicksburg, Mississippi
1	Commanding Officer Frankford Arsenal ATTN: Library Branch, 0270 Bldg. 40 Philadelphia, Pennsylvania 19137	1	Commanding Officer U. S. Army Research Office (Durham) Box CM, Duke Station Durham, North Carolina 27706
1	Commanding Officer Picatinny Arsenal ATTN: Feltman Research and Engineering Laboratories Dover, New Jersey 07801	2	Assistant Chief of Staff, G-2 Technical Branch Department of the Army Washington 25, D. C.

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
3	Chief, Bureau of Naval Weapons ATTN: DLI-3 Department of the Navy Washington, D. C. 20360	4	Director U. S. Naval Research Laboratory Washington, D. C. 20390
1	Chief, Bureau of Ships Code 1500 Department of the Navy Washington, D. C. 20360	2	Commander U. S. Naval Weapons Laboratory ATTN: Technical Library Dr. William G. Soper Dahlgren, Virginia 22448
1	Chief, Bureau of Yards & Docks Department of the Navy Washington, D. C. 20360	20	Commanding Officer Office of Naval Research Box 39, Navy 100 FPO, New York, New York
1	Chief of Naval Operations Department of the Navy Washington, D. C. 20360	2	AFWL (SWRS, Tech Info & Intell Ofc) Kirtland Air Force Base New Mexico 87117
1	Chief of Naval Research Department of the Navy Washington 25, D. C.	13	ASD (ASAPRD) Wright-Patterson Air Force Base Ohio 45433
5	Commander U. S. Naval Ordnance Laboratory ATTN: Library (4 cys) Dr. Walter R. Wise, Jr. White Oak Silver Spring 19, Maryland	1	AFIT (Library) Wright-Patterson Air Force Base Ohio 45433
2	Commander U. S. Naval Ordnance Test Station ATTN: Technical Library E. A. Zeitlin (Code 45419) China Lake, California 93557	1	Director, Project RAND ATTN: Librarian Department of the Air Force 1700 Main Street Santa Monica, California 90406
1	Library U. S. Naval Postgraduate School ATTN: Technical Reports Section Monterey, California	2	U. S. Geological Survey Denver Federal Center ATTN: Librarian Denver, Colorado
		1	U. S. Geological Survey ATTN: Staff Geologist P. O. Box 4072 Albuquerque, New Mexico

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
2	U. S. Geological Survey General Services Administration Building ATTN: Librarian, Room 1033 Chief, Radiohydrology Section WR Division Room 2235 Washington 25, D. C.	2	Assistant Chief, Division of Radiological Health U. S. Public Health Service Room 5094, South Building 4th and C Streets, S. W. Washington 25, D. C.
1	U. S. Geological Survey Geochemistry and Petrology Branch Naval Gun Factory, Building 213 Washington 25, D. C.	1	U. S. Patent Office Scientific Library Washington 25, D. C.
1	Director National Aeronautics and Space Administration Lewis Research Center ATTN: Librarian Cleveland Airport Cleveland, Ohio	1	The Maritime Administration U. S. Department of Commerce New GAO Building Washington 25, D. C.
1	National Academy of Sciences The AMSOT Committee ATTN: Technical Director 2101 Constitution Avenue, N. W. Washington 25, D. C.	4	U. S. Atomic Energy Commission ATTN: Technical Library Washington 25, D. C.
1	Bureau of Mines Region 1 P. O. Box 492 Albany, Oregon	1	U. S. Atomic Energy Commission Army Reactors Division of Reactor Development Washington 25, D. C.
5	Director National Bureau of Standards U. S. Department of Commerce ATTN: Radiation Physics Laboratory Library Coordinator of Atomic Energy Projects Dr. Krupenie, Bldg. 138 Dr. C. Muchlhaue Washington 25, D. C.	1	U. S. Atomic Energy Commission Civilian Reactors Division of Reactor Development ATTN: Mr. A. Giambusso Washington 25, D. C.
		1	U. S. Atomic Energy Commission Maritime Reactors Branch Division of Reactor Development Washington 25, D. C.
		2	U. S. Atomic Energy Commission Naval Reactors Branch Division of Reactor Development ATTN: Mr. T. Rockwell Mr. R. S. Brodsky Washington 25, D. C.

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
5	U. S. Atomic Energy Commission Research and Development Branch Division of Reactor Development ATTN: Mr. S. A. Szawlewicz Washington 25, D. C.	1	U. S. Atomic Energy Commission Canoga Park Area Office ATTN: Mr. C. W. Richards P. O. Box 591 Canoga Park, California
1	U. S. Atomic Energy Commission Chicago Operations Office ATTN: Mr. O. M. Gardiner 9800 South Cass Avenue Argonne, Illinois	1	U. S. Atomic Energy Commission Hartford Area Office P. O. Box 1102 Middletown, Connecticut
1	U. S. Atomic Energy Commission Grand Junction Operations Office ATTN: Director, Information Division Grand Junction, Colorado	1	U. S. Atomic Energy Commission New Brunswick Area Office P. O. Box 150 New Brunswick, New Jersey
2	U. S. Atomic Energy Commission Idaho Operations Office ATTN: Mr. G. E. Devore Mr. D. Williams P. O. Box 2102 Idaho Falls, Idaho	1	U. S. Atomic Energy Commission Division of Compliance Washington 25, D. C.
2	U. S. Atomic Energy Commission New York Operations Office ATTN: Document Custodian 376 Hudson Street New York 14, New York	1	U. S. Atomic Energy Commission Division of Compliance, Region IV ATTN: John W. Flora P. O. Box 15266 Denver 15, Colorado
1	U. S. Atomic Energy Commission Oak Ridge Operations Office P. O. Box 8 Oak Ridge, Tennessee	1	U. S. Atomic Energy Commission Chief, Patent Branch 1717 H Street, N. W. Washington 25, D. C.
1	U. S. Atomic Energy Commission San Francisco Operations Office ATTN: Lt. Col. John B. Radcliffe 2111 Bancroft Way Berkeley 4, California	1	U. S. Atomic Energy Commission Chicago Patent Group P. O. Box 59 Lemont, Illinois
1	U. S. Atomic Energy Commission Chicago Operations Office ATTN: Mr. O. M. Gardiner 9800 South Cass Avenue Argonne, Illinois	10	U. S. Atomic Energy Commission Reference Branch Division of Technical Information Extension P. O. Box 62 Oak Ridge, Tennessee
		1	U. S. Atomic Energy Commission Division of Construction & Supply Washington 25, D. C.

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
7	U. S. Atomic Energy Commission Division of Licensing and Regulation ATTN: Mr. Edson G. Case Mr. Joseph J. DiNunno Washington 25, D. C.	5	Oak Ridge National Laboratory ATTN: Dr. W. K. Ergen Dr. F. A. Gifford Mr. William B. Cottrell Mr. Frank Bruce Dr. F. C. Maienschein P. O. Box X Oak Ridge, Tennessee
1	U. S. Atomic Energy Commission Hazards Evaluation Branch Division of Licensing & Regulation Washington 25, D. C.	1	Oak Ridge Institute of Nuclear Studies ATTN: Library P. O. Box 117 Oak Ridge, Tennessee
3	U. S. Atomic Energy Commission Advisory Committee on Reactor Safeguards ATTN: Mr. R. F. Fraley Washington 25, D. C.	1	Sandia Corporation Sandia Base ATTN: Library P. O. Box 5800 Albuquerque, New Mexico 87115
2	Argonne National Laboratory ATTN: Dr. R. C. Vogel 9700 S. Cass Avenue Argonne, Illinois	1	Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena 3, California
6	Brookhaven National Laboratory ATTN: Research Library (4 cys) Dr. Herbert J. C. Kouts Mr. A. W. Castleman Upton, Long Island, New York	1	ACF Industries, Inc. 508 Kennedy Street, N. W. Washington, D. C.
4	University of California Lawrence Radiation Laboratory Technical Information Division P. O. Box 808 Livermore, California	2	Aerojet-General Corporation ATTN: Librarian H. M. Higgins Underwater Engine Div. 6552 North Irwindale Road Azusa, California
5	Los Alamos Scientific Laboratory ATTN: Reports Librarian (4 cys) Mr. David B. Hall P. O. Box 1663 Los Alamos, New Mexico 87544	1	Aerojet-General Nuclearonics ATTN: Barbara Aaron AT(10-1)-880 P. O. Box 78 San Ramon, California
6	Oak Ridge National Laboratory P. O. Box P Oak Ridge, Tennessee	1	Aeronautics, Inc. 158 North Hill Avenue Pasadena, California

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
2	Aerospace Corp ATTN: Library, Technical Documents Group P. O. Box 95085 Los Angeles 45, California	1	Atomic Power Development Associates 2000 Second Avenue Detroit 26, Michigan
1	Aircraft Armaments, Inc. ATTN: Dr. W. E. Baker P. O. Box 126 Cockeysville, Maryland	6	Atomics International ATTN: Library (4 cys) Mr. A. A. Jarrett P. O. Box 309 Canoga Park, California
1	Alco Products, Inc. P. O. Box 414 Schenectady 5, New York	1	AVCO Corporation Research & Advanced Development Division ATTN: Assistant Chief, Applied Mechanics Section 201 Lowell Street Wilmington, Massachusetts
1	Allied Chemical & Dye Corp ATTN: Manager, Central Engineering Morristown, New Jersey	4	Tabacco and Wilcox Company ATTN: Information Service 1201 Kemper Street Lynchburg, Virginia
1	Allied Chemical & Dye Corp General Chemical Division ATTN: Mr. K. R. Osborn Manager, Industrial Development 40 Rector Street New York 6, New York	2	Battelle Memorial Institute 505 King Avenue Columbus 1, Ohio
1	Allis Chalmers Manufacturing Co. Nuclear Power Department Box 512 Milwaukee 1, Wisconsin	1	Beryllium Corporation P. O. Box 1462 Reading, Pennsylvania
1	American Machine & Foundry Co. General Engineering Laboratories Nuclear Laboratory 11 Bruce Place Greenwich, Connecticut	1	Boeing Airplane Co., Plant II Sacramento Air Materiel Area Seattle 14, Washington
1	American Standard Atomic Energy Division P. O. Box 1057 Mountain View, California	1	Brush Beryllium Company 4301 Perkins Avenue Cleveland 3, Ohio
1	Arthur D. Little, Inc. ATTN: Library 15 Acorn Park Cambridge 40, Massachusetts	2	Combustion Engineering, Inc. Nuclear Division ATTN: Document Custodian Windsor, Connecticut

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	CONVAIR - San Diego ATTN: Librarian P. O. Box 1950 San Diego 12, California	1	General Electric Company Vallecitos Atomic Laboratory P. O. Box 846 Pleasanton, California
1	Curtiss-Wright Corp Research Division ATTN: AEC Contract Document Custodian Nuclear Power Department P. O. Box 102 Quehanna, Pennsylvania	2	General Electric Company Aircraft Nuclear Propulsion Department Research Information Unit Cincinnati 15, Ohio
1	Dow Chemical Company Rocky Flats Plant ATTN: Librarian P. O. Box 2131 Denver, Colorado	6	General Electric Company P. O. Box 100 Richland, Washington
4	E. I. du Pont de Nemours & Co. Savannah River Laboratory Technical Information Service - 773A Aiken, South Carolina	2	General Electric Company Knolls Atomic Power Laboratory ATTN: Document Librarian P. O. Box 1072 Schenectady, New York
1	E. I. du Pont de Nemours & Co. Explosives Department ATTN: Document Custodian Atomic Energy Division Wilmington 98, Delaware	1	General Electric Company Atomic Power Equipment Department P. O. Box 1131 San Jose, California
1	Franklin Institute Laboratories Benjamin Franklin Parkway at 20th Street Philadelphia 3, Pennsylvania	1	General Electric Company Engineering Corp ATTN: AT (58-1)-143 P. O. Box 245 Dunedin, Florida
2	General Dynamics Corporation General Atomic Division ATTN: Document Custodian P. O. Box 8, Old San Diego Station San Diego 10, California	1	Gibbs and Cox, Inc. 21 West Street New York 6, New York
2	General Electric Company ANP Department Cincinnati 15, Ohio	1	Goodyear Atomic Corporation ATTN: Library, Bldg. X-710 P. O. Box 628 Portsmouth, Ohio
		1	Hercules Powder Company ATTN: Manager, Physical Chemical Division Research Department Wilmington, Delaware

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Holmes and Narver, Inc. 828 South Figueroa Street Los Angeles 17, California	1	National Distillers & Chemical Corporation Bridgeport Brass Division 30 Grand Street Bridgeport 2, Connecticut
1	Hughes Aircraft Company ATTN: Gunter, M/S ED 136 Systems Development Laboratories Culver City, California	1	National Distillers & Chemical Corporation Bridgeport Brass Division East 21st Street P. O. Box 588 Ashtabula, Ohio
1	Inter nuclear Company 7 North Brentwood Boulevard Clayton 5, Missouri	1	National Lead Company of Ohio ATTN: Reports Library P. O. Box 158 Mount Healthy Station Cincinnati 39, Ohio
1	Kaman Nuclear ATTN: Librarian Division of Kaman Aircraft Corp. Colorado Springs, Colorado 80907	1	National Lead Company, Inc. Raw Materials Development Lab. Holton Street Winchester, Massachusetts
1	Liberty Mutual Insurance Company ATTN: Dr. C. R. Williams 175 Berkeley Street Boston 17, Massachusetts	1	Northern Research & Engineering Corporation Manager of Engineering 238 Main Street Cambridge 38, Massachusetts
1	Lockheed Aircraft Corporation Lockheed Missiles & Space Division Palo Alto, California	1	Nuclear Metals, Inc. P. O. Box 222 Concord, Massachusetts
2	Lockheed Aircraft Corporation Marietta, Georgia	10	Phillips Petroleum Company ATTN: Mr. Glenn O. Bright Mr. Warren E. Ryer Mr. Frank Schroeder Mr. T. R. Wilson Library - NRTS P. O. box 1259 Idaho Falls, Idaho
1	Mallinckrodt Chemical Works Uranium Division ATTN: Technical Library P. O. Box 472 St. Charles, Missouri		
1	The Martin Company ATTN: AEC Document Library (217) Baltimore, Maryland 21203		
1	Monsanto Chemical Company Mound Laboratory P. O. Box 32 Miamisburg, Ohio		

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Power Reactor Development Co. ATTN: Document Custodian - AT (11-1)-476 1911 First Street Detroit 26, Michigan	1	The Travelers Insurance Co. ATTN: Assistant Director, Department of Research 700 Main Street Hartford 15, Connecticut
3	Pratt & Whitney Aircraft Division Connecticut Operations - CANEI ATTN: Library P. O. Box 611 Middletown, Connecticut	2	Union Carbide Nuclear Company ORNDORF Records Department P. O. Box F Oak Ridge, Tennessee
1	Ramo Wooldridge Corporation 8433 Fallbrook Avenue Canoga Park, California	1	Union Carbide Nuclear Company Y-12 Technical Library, Bldg. 9711-1 P. O. Box Y Oak Ridge, Tennessee
1	Space Technology Laboratories, Inc. P. O. Box 1085 Los Angeles 45, California	5	Union Carbide Nuclear Company X-10 Laboratory Records Department P. O. Box X Oak Ridge, Tennessee
2	Space Technology Laboratories, Inc. ATTN: Dr. D. B. Langmuir Mr. S. M. Zivi One Space Park Redondo Beach, California	1	Union Carbide Nuclear Company ATTN: Library P. O. Box 1223 Paducah, Kentucky
1	Sylvania Electric Products, Inc. Atomic Energy Division ATTN: Reports Custodian P. O. Box 59 Bayside, New York	2	United Nuclear Corporation Development Division ATTN: Records Management Document Custodian Dr. C. Graves 5 New Street White Plains, New York
1	Technical Research Group ATTN: Library 2 Aerial Way Syosset, Long Island, New York	1	Vitro Engineering Division Technical Reports Sections ATTN: William E. Downey 100 Church Street New York, New York
1	Tennessee Valley Authority ATTN: Mr. William E. Dean, Jr. Assistant Director of Power Supply Chattanooga, Tennessee		

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
2	Westinghouse Electric Corp Atomic Power Department ATTN: Mr. E. Schafer - Contract AT (30-3)-222 P. O. Box 355 Pittsburgh 30, Pennsylvania	1	Harvard University ATTN: Dean of Engineering and Applied Physics Cambridge, Massachusetts
4	Westinghouse Electric Corp Bettis Atomic Power Laboratory P. O. Box 1468 Pittsburgh 30, Pennsylvania	1	Harvard University School of Public Health ATTN: Dr. Leslie Silverman 55 Shattuck Street Boston 15, Massachusetts
1	Yankee Atomic Electric Co ATTN: SOO Contract Document Custodian P. O. Box 346 Boston 16, Massachusetts	2	Iowa State College P. O. Box 14A, Station A Ames, Iowa
1	Aurora College Aurora , Illinois	2	IIT Research Institute ATTN: Dr. T. A. Zaker Dr. M. A. Salmon 10 W. 35th Street Chicago, Illinois 60616
1	Carnegie Institute of Technology ATTN: Business Manager - 882 Department of Physics Pittsburgh 13, Pennsylvania	1	The Johns Hopkins University ATTN: Professor James P. Bell Department of Mechanical Engineering Baltimore, Maryland
1	Cornell University ATTN: Dr. John P. Howe Ithaca, New York	1	The Johns Hopkins University Department of Sanitary and Water Resources ATTN: Dr. John C. Geyer Baltimore 18, Maryland
1	Denver Research Institute University of Denver Denver 10, Colorado	1	Massachusetts Institute of Technology Department of Nuclear Engineering ATTN: Dr. Theo J. Thompson Cambridge 39, Massachusetts
1	Draxel Institute of Technology ATTN: Dean, College of Engineering Philadelphia 4, Pennsylvania	1	New York University AEC Computing & Applied Mathematics Center 25 Waverly Place New York 3, New York
1	Duke University Department of Physics ATTN: Dr. N. W. Ewson Durham, North Carolina	1	Pennsylvania State University Department of Physics University Park, Pennsylvania

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Princeton University Department of Physics Princeton, New Jersey	1	University of Maryland Department of Chemical Engineering ATTN: Dr. Dick Duffey Professor of Nuclear Engineering College Park, Maryland
2	Rensselaer Polytechnic Institute ATTN: Document Custodian Troy, New York	1	University of Minnesota Department of Chemical Engineering ATTN: Professor H. Isbin Minneapolis, Minnesota
1	South Dakota School of Mines and Technology ATTN: Library Rapid City, South Dakota	1	University of Rochester Atomic Energy Project ATTN: Technical Report Control Unit P. O. Box 287, Station 3 Rochester 20, New York
3	Stanford Research Institute Poulter Laboratory Menlo Park, California	2	University of Rochester Department of Physics Rochester, New York
1	Stevens Institute of Technology Department of Physics Hoboken, New Jersey	1	University of Utah ATTN: Business Manager Radiobiology Laboratory Salt Lake City 12, Utah
3	University of California Radiation Laboratory Information Division Room 128, Bldg. 50 Berkeley, California	1	University of Washington ATTN: Professor Ronald Gehalle Department of Physics Seattle 5, Washington
2	University of California Institute of Engineering Research ATTN: Prof. H. A. Johnson Dr. V. E. Schrock Berkeley 4, California	1	Cyclotron University of Washington Seattle 5, Washington
1	University of Hawaii Honolulu 14, Hawaii	1	Valparaiso University ATTN: Dean, College of Engr. Valparaiso, Indiana
1	University of Illinois Department of Theoretical and Applied Mechanics ATTN: Professor W. J. Worley Talbot Laboratory Urbana, Illinois	1	Dr. Amasa S. Bishop, Scientific Representative U. S. Atomic Energy Commission c/o American Embassy, Paris, France c/o Department of State Washington 25, D. C.

# DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Dr. Samuel Glasstone RFD 1 P. O. Box 322 Santa Fe, New Mexico	1	USAMC Liaison Office ATTN: Mr. Glenn D. Boyer P. O. Box 905 Toronto 18, Ontario Canada
1	Mr. B. E. Cummings Engineering Bldg. III Room 5731 K College of Engineering University of California Los Angeles 24, California	1	The Royal Military College of Canada ATTN: Professor J. W. Dolphin Department of National Defence Kingston, Ontario Canada
1	Mr. Gunnar Randers Secretary to the UN Scientific Committee on the Effects of Atomic Radiation UN Building New York, New York	1	University of Puerto Rico Puerto Nuclear Center College Station Mayaguez, Puerto Rico
1	Mr. D. A. Rogers 11 Lingerwood Pl. Morristown, New Jersey	4	Australian Group c/o Military Attache Australian Embassy 2001 Connecticut Avenue, N. W. Washington, D. C. 20008
1	Mr. R. C. Stratton Apartment 5 J 98 Garden Street Hartford 5, Connecticut	10	The Scientific Information Officer Defence Research Staff British Embassy 3100 Massachusetts Avenue, N. W. Washington, D. C. 20008
1	W. W. Boynton, Director Boynton Associates 1018 Olive Lane La Canada, California	8	Defence Research Member Canadian Joint Staff 2450 Massachusetts Avenue, N. W. Washington, D. C. 20008
1	Mr. W. Herbert Pennington AEC Scientific Representative U. S. Embassy Tokyo, Japan		Of Interest to:
1	Dr. Nathan H. Woodruff AEC Scientific Representative U. S. Embassy Buenos Aires, Argentina		Atomic Energy of Canada Limited ATTN: John E. Woolston, Technical Information Officer Chalk River, Ontario Canada

## Aberdeen Proving Ground

Chief, TIS  
Air Force Liaison Office  
Marine Corps Liaison Office  
Navy Liaison Office  
CDC Liaison Office  
D&PS Branch Library

AD  
Ballistic Research Laboratories, AR  
THE PLASTIC RESPONSE TO INTERNAL BLAST  
LOADING OF MODELS OF OTHER CONTAINMENT  
STRUCTURES FOR NUCLEAR REACTORS  
J. V. Hanna, W. O. Ewing, Jr.  
UNCLASSIFIED

BRL Memorandum Report No. 1590 January 1964

RDT & E Project No. DM010901A006  
UNCLASSIFIED Report

Accession No.  
Structures - Blast effect  
Atomic power plants  
Elastic shells -  
Deformation

Presented are results of an experimental investigation of the plastic response of two geometrically scaled models of nuclear reactor outer containment vessels to internal blast loading. Tests were performed to study the ability of the containment shells to maintain integrity when subjected to large amounts of explosively released energy when unsupported (suspended in air), when half-buried in the ground, and when half-embedded in concrete. The results show that the vessels tested will withstand a relatively large amount of explosively released energy, as compared to the "maximum credible incident" expected, provided that the welds are adequate and that access or other openings are properly reinforced.

AD  
Ballistic Research Laboratories, AR  
THE PLASTIC RESPONSE TO INTERNAL BLAST  
LOADING OF MODELS OF OTHER CONTAINMENT  
STRUCTURES FOR NUCLEAR REACTORS  
J. V. Hanna, W. O. Ewing, Jr.  
UNCLASSIFIED

BRL Memorandum Report No. 1590 January 1964

RDT & E Project No. DM010901A006  
UNCLASSIFIED Report

Accession No.  
Structures - Blast effect  
Atomic power plants  
Elastic shells -  
Deformation

Presented are results of an experimental investigation of the plastic response of two geometrically scaled models of nuclear reactor outer containment vessels to internal blast loading. Tests were performed to study the ability of the containment shells to maintain integrity when subjected to large amounts of explosively released energy when unsupported (suspended in air), when half-buried in the ground, and when half-embedded in concrete. The results show that the vessels tested will withstand a relatively large amount of explosively released energy, as compared to the "maximum credible incident" expected, provided that the welds are adequate and that access or other openings are properly reinforced.

AD  
Ballistic Research Laboratories, AR  
THE PLASTIC RESPONSE TO INTERNAL BLAST  
LOADING OF MODELS OF OTHER CONTAINMENT  
STRUCTURES FOR NUCLEAR REACTORS  
J. V. Hanna, W. O. Ewing, Jr.  
UNCLASSIFIED

BRL Memorandum Report No. 1590 January 1964

RDT & E Project No. DM010901A006  
UNCLASSIFIED Report

Accession No.  
Structures - Blast effect  
Atomic power plants  
Elastic shells -  
Deformation

Presented are results of an experimental investigation of the plastic response of two geometrically scaled models of nuclear reactor outer containment vessels to internal blast loading. Tests were performed to study the ability of the containment shells to maintain integrity when subjected to large amounts of explosively released energy when unsupported (suspended in air), when half-buried in the ground, and when half-embedded in concrete. The results show that the vessels tested will withstand a relatively large amount of explosively released energy, as compared to the "maximum credible incident" expected, provided that the welds are adequate and that access or other openings are properly reinforced.

AD  
Ballistic Research Laboratories, AR  
THE PLASTIC RESPONSE TO INTERNAL BLAST  
LOADING OF MODELS OF OTHER CONTAINMENT  
STRUCTURES FOR NUCLEAR REACTORS  
J. V. Hanna, W. O. Ewing, Jr.  
UNCLASSIFIED

BRL Memorandum Report No. 1590 January 1964

RDT & E Project No. DM010901A006  
UNCLASSIFIED Report

Accession No.  
Structures - Blast effect  
Atomic power plants  
Elastic shells -  
Deformation

Presented are results of an experimental investigation of the plastic response of two geometrically scaled models of nuclear reactor outer containment vessels to internal blast loading. Tests were performed to study the ability of the containment shells to maintain integrity when subjected to large amounts of explosively released energy when unsupported (suspended in air), when half-buried in the ground, and when half-embedded in concrete. The results show that the vessels tested will withstand a relatively large amount of explosively released energy, as compared to the "maximum credible incident" expected, provided that the welds are adequate and that access or other openings are properly reinforced.